The hidden role of water on earth

By Fanie Vorster (PrEng), Institute of Agricultural Engineering

Water is the most precious substance on earth, a fact which has been undisputed throughout history. Water has unique properties that are required for life. This article focuses on the importance of water in stabilising the earth's climate.

The wonder of water

There are approximately 1,4 billion km^3 of water on earth. It is found in different environments and in three distinct phases.

Next time you drink a glass of ice water, consider that you are experiencing water in all three its phases. The solid ice cools the liquid in your glass, and the air you breathe is full of water vapour. This is possible because it can naturally exist in all three its phases in the temperature and pressure ranges that are common on earth.

Ice in the polar regions freezes and thaws with the seasons and plays a crucial role in regulating the earth's climate. Water also has a remarkable ability to absorb and retain heat. The sun delivers a tremendous amount of energy to the earth every day and the tropical oceans absorb much of that energy. In addition, a lot of it goes to creating water vapour, which is the source of all rain and snow. The 13 trillion tons of water in the atmosphere is responsible for absorbing approximately 70% of all atmospheric radiation from the sun.

Water in different environments

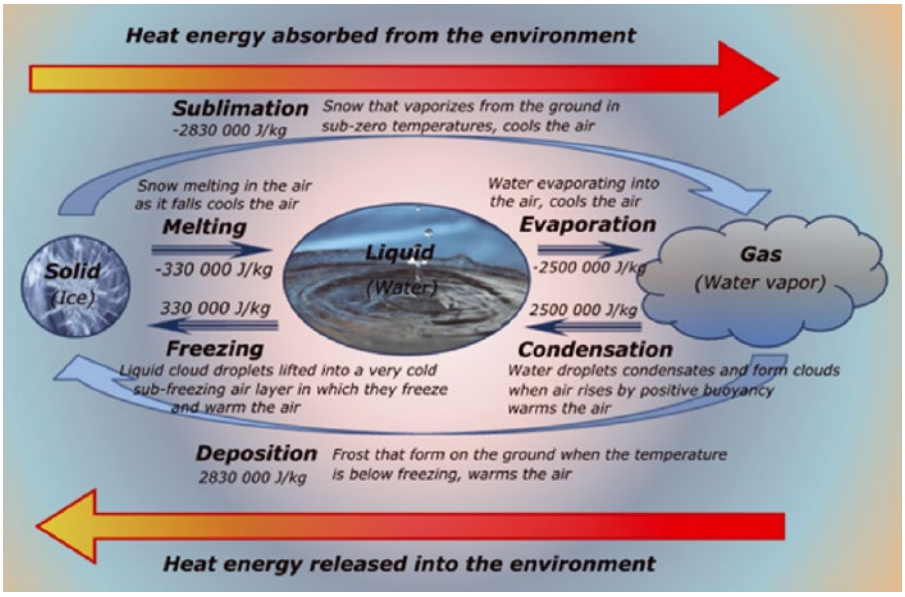
Phase change depends on temperature and pressure. During each phase change a specific amount of latent heat is either absorbed or released without the sensible temperature changing. These different processes contribute to cooling and warming the air in the troposphere (*Figure 1*).

The oceans contain approximately 97,25% of the total volume of water on earth and cover 70,8% of the planet's surface. The water in the oceans plays a key role in regulating temperatures across the globe.

Water on land consists of the following:

- Water is found in solid form in snow and glaciers, which comprise 2,05% of the volume of all water on earth. It contains nearly 70% of the world's fresh water.
- Only 0,0001% of visible surface water is found in rivers.

Figure 1: The phase changes of water.



- Lakes and inland seas make up 0,01% of the volume of all water on earth.
- Groundwater comprises 0,68%.
- The moisture in soil makes up 0,005% of the volume of all water on earth.

The volume of water in the atmosphere is almost ten times greater than the volume of water in all rivers. Atmospheric water plays a crucial role in regulating local temperature.

Water in living organisms includes water in humans, animals and plants, and makes up approximately 0,00004% of the volume of all water on earth.

The regulating effect of water

Water plays a significant role in balancing the temperature extremes between the seasons, day and night, and different regions. Water vapour is the most abundant greenhouse gas in the atmosphere and its concentration varies between 1 and 4%, while the average concentration of CO_2 is 0,0383%.

When there is more water vapour present in the atmosphere, temperatures are moderated to a greater extent with subsequent fewer extreme variations in the weather. Practical experience shows that where water is lacking in the soil and atmosphere, extreme thermal conditions usually predominate, as experienced in arid and desert regions.

Clouds play a crucial role in regulating the energy balance of solar radiation on earth. Clouds usually shadow half the earth's surface at any given time. Low altitude clouds limit the entry of solar radiation into the atmosphere, which limits evaporation and thus the further formation of clouds.

Thin, high-altitude clouds retain some of the longwave thermal radiation that is emitted from the surface of the earth into space, thereby preventing excessive cooling of the planet's surface.

The earth's water cycle

The sun provides the energy to facilitate the phase changes of water. The oceans, land and atmosphere store all the water on earth in an equilibrium, called the water cycle (*Figure 2*), of different phases and environments.

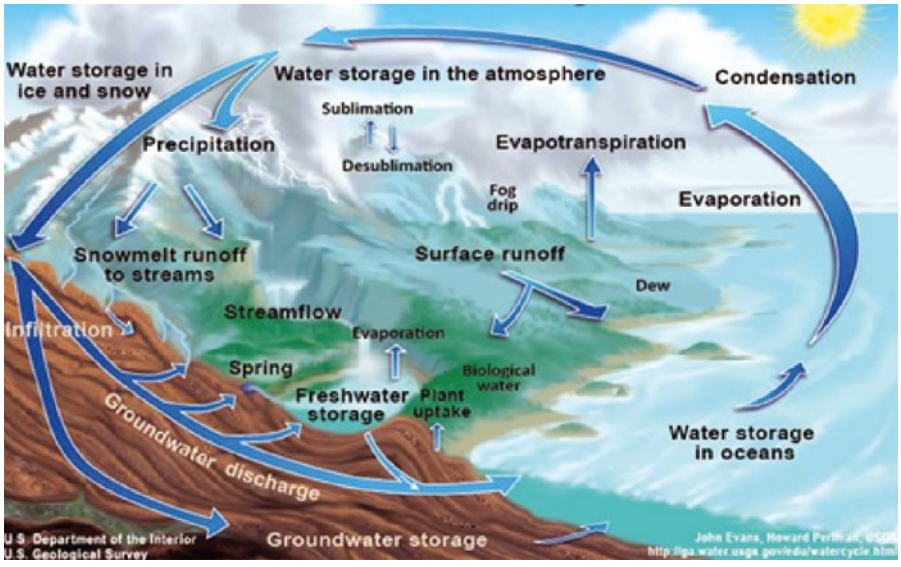
The ability of water to absorb and release a large amount of heat allows the earth's climate to be well balanced, with an annual turnover of vast amounts of water in the water cycle. There are four main stages in this cycle, namely evaporation, condensation, precipitation and runoff.

When the sun shines, water evaporates and turns into water vapour, which goes into the atmosphere and turns into clouds. When clouds become dense, the water drops to the earth in some form of precipitation, such as rain, snow, hail or sleet.

Some of it infiltrates into the soil for use by plants or evaporates from the soil. Water that infiltrates deeper could emerge as springs at a lower elevation, while water that does not infiltrate into the soil concentrates on its surface. From here it evaporates or flows to the ocean, from where it evaporates again.

Throughout this continuous movement of water it is purified, and it drives, cleans and regulates ecosystems. The water cycle has two primary components, namely the large water cycle and the small water cycle (*Figure 3*).

Figure 2: The water cycle by John Evans and Howard Perlman. (Source: United States Geological Survey, USGS)



The large water cycle

The large water cycle is the exchange of water between oceans and land. Globally nearly 550 000km^3 of water evaporates annually – around 86% evaporates from the oceans and the remaining 14% from land. Each year 74% of the precipitation that results from this evaporation falls over the oceans and the remaining 26% on land. Roughly 12% of the precipitation that occurs on land is derived from water that evaporated from the oceans. Water vapour is carried inland from the ocean, over great distances, high in the atmosphere (*Figure 3)*.

The small water cycle

The small or local water cycle is a closed circulation of water on land or over the oceans and is characteristic of a hydrologically healthy area. Water that has evaporated from an area falls as precipitation in more or less the same terrestrial area.

Water is circulated over the continents in many small water cycles simultaneously. Water from the large water cycle is added to these small water cycles. The extent to which moisture saturates soil in a region influences the precipitation in that specific area and its surroundings.

Disturbances in the equilibrium

Even relatively slight disturbances in the balance of this water system, especially over the long term and spread over many river catchments, could cause problems on land.

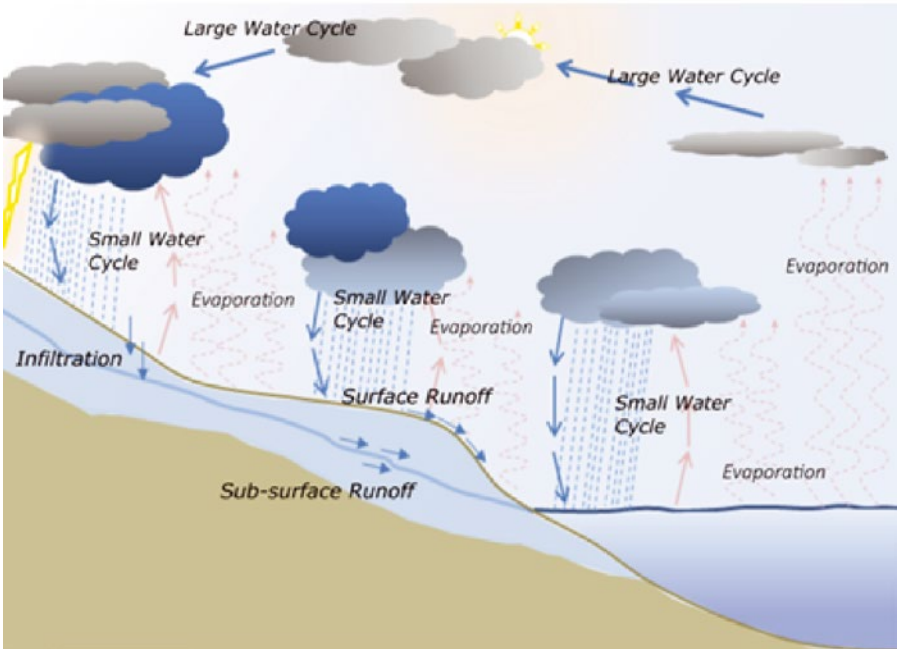
This can occur when the volume of rainwater that infiltrates into the soil is reduced. This will cause a gradual decrease in the volume of water in the small water cycle over land, resulting in a subsequent reduction in precipitation and an increase in temperature.

This global phenomenon has occurred throughout history and its cause can be attributed to several human activities. Over time the soil moisture content decreases, the subsurface water table declines,

vegetation withers and less evaporation takes place from the land.

To ensure that the ecosystem in a river downstream from a reservoir survives, a certain streamflow is allocated and managed according to the ecosystem needs of the remaining length of the river. In the same way it is necessary to consider the water that needs to circulate in the water cycle in order to maintain the entire ecosystem. Consequently, we should not just consider the water that we see, but also the water in the remainder of the water cycle, namely the atmosphere, soil and in vegetation.

Figure 3: A schematic representation of the large- and small water cycles.



Factors affecting the balance

There is a perception that over long periods and for large areas this difference in water entering a system and water leaving the system is close to zero. However, evidence shows that sea levels are rising, and experience teaches us that the water reserves on land are declining.

Several external factors beyond the influence of humans affect the global balance of water. However, human activities result in a further disturbance of this balance on a global scale, contributing to the desertification of continents. Nevertheless, it could be possible to rectify the problem through deliberate conservation of water on continents. SF

For more information and references, phone the author on 012 842 4052 or send an email to vorsters@arc.agric.za.